(WO/1998/049434) INTERNAL COMBUSTION ENGINE

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Title: (EN) INTERNAL COMBUSTION ENGINE
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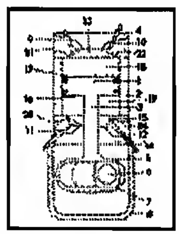
Abstract: (EN) An internal combustion engine having a single piston (1) dual chamber (18, 19) arrangement wherein at least one chamber (18) is a combustion chamber. A connecting rod (3) is rigidly coupled to the piston (1) and passing out of a chamber (19) to be coupled to a linear to rotary motion converter.

(FR) L'invention a trait à un moteur à combustion interne muni d'un mécanisme à deux chambres (18, 19), doté d'un seul piston (1), à l'intérieur duquel au moins une chambre (18) est une chambre de combustion. Une bielle (3) est couplée de manière rigide au piston (1) et ressort d'une chambre (19) en vue d'être couplée à un convertisseur de mouvement linéaire en mouvement giratoire.



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(WO/1998/049434) INTERNAL COMBUSTION ENGINE

"INTERNAL COMBUSTION ENGINE" Technical Field The invention relates to internal combustion engines of the piston and cylinder type and more particularly to such engines which can be made compact and lighter than conventional engines. A more compact and lighter engine has been a continual design goal and is of benefit to the automotive industry and others in that less materials are used, the space required to fit the engine is less end a lighter weight engine means that other components in the vehicle can be lighter and less expensive.

Disclosure of Invention Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element or integer or group of elements or integers but not the exclusion of any other element or integer or group of elements or integers.

In accordance with the present invention there is provided an internal combustion engine including a piston rigidly coupled to a connecting rod, said piston being fitted within e cylinder having e chember at each end thereof, said connecting rod passing out of the cylinder through an end face of at least one of said chambers, at least one of said chambers being a combustion chamber and said connecting rod being coupled to means for converting linear motion to rotary motion.

With an engine configuration of this Invention it is practical to make provision for more than one piston to be attached to each connecting rod and a chamber provided for each side of each piston. The additional chambers can be used to provide a means of supercharging the engine or of providing secondary expansion of gases.

The design of one embodiment of this engine provides for combustion to occur on both sides of each piston and for the piston to be connected to a connecting rod which is rigidly attached to the piston as opposed to the more conventional wrist pin connection and moves in the same plane as the piston in contrast to a conventional piston which moves leterelly to conform to the movement of the cranksheft; The connecting rod is connected to a means of converting a linear motion to a rotary motion and such means can include but are not limited to a Scotch yoke connected to a crankshaft, an epicycloidal crank mechanism or a second connecting rod which is articulated and connected to a crankshaft.

A second cylinder head is incorporated on the same side of the piston as the connecting rod and the rod moves through a bushed and sealed circular machined aperture in the cylinder head where it is joined to a means of converting linear motion to rotary motion and the power generated by the piston is transferred through the connecting rod to the conversion means to e power shaft which is typically a crankshaft.

The benefits of such an arrangement are that the piston can be very short as there is no necessity to provide a long piston skirt as there is little side thrust on the piston and the connecting rod provides a second means of guidance for the piston/rod combination and this shortens the length of the cylinder, the ability to develop power relative to weight is greatly enhanced due to the second combustion chamber operating in the same cylinder and by means of the same connecting rod and the same crankshaft throw.

The challenges posed by the second combustion chamber are that it is difficult to provide the means for operating valves by conventional mechanisms, the problem of possible overheating of the piston due to its exposure to close to twice the amount of combustion heat than conventional configurations, the problems of heating of the connecting rod which is directly exposed to the heat of combustion, the problems of lubricating the cylinder walls, the problems of combustion characteristics caused by the intrusion of the connecting rod into the combustion chamber, and the problems of propagating the flame front if one conventional spark plug is used.

The problem of providing means of operating the velves is minimised if electronicelly controlled valve actuetors are

used. There are a variety of such actuators and actuation can be by mechanical/hydraulic, electro- mechanical, pneumatic, electro-magnetic; piezo-ceramic or other means. An example of such an actuator is shown in WO 97/19260, the contents of which are incorporated herein by reference. A preferred configuration for the engine herein will feature individually actuated inlet and exhaust valves controlled by an engine management system.

Individual actuation allows the secondary cylinders, by which is meant the cylinders into which the connecting rods protrude, to be de-ectivated when not required, that is, under conditions of light load. This allows the cylinders still operating to operate under higher compressions and thus to operate at a higher efficiency. Many other benefits can be gained by the operation of individually actuated valves, some of which are mentioned above.

The problem of possible overheating of the piston and connecting rod, and the problems of lubricating the cylinder walls can be overcome by a system of circulating engine oil which both lubricates and cools the piston and connecting rod. This is a preferred solution although it would be possible to circulate an alternate coolant for cooling purposes as well as oil for lubrication. There are various ways that circutation of oil can be achieved.

Oil can be supplied under pressure through a gallery in the cytinder wall to supply oil under pressure between the upper and lower piston rings and to force oil into galleries in the piston which then circulate oil through the connecting rod to an aperture in the connecting rod which is close to the point of attachment to the conversion means in the crankcase so that oil is dumped into the crankcase area. This method requires a piston long enough that the holes in the cylinder wall are not uncovered by the piston. A means such as electrically or mechanically operated valve can be provided to cut the supply of oil when such a hole is uncovered by the piston to alleviate the problem of uncovering the oil gallery when a short piston is used.

Another means of lubrication is by means of an aperture in the connecting rod which is positioned so that it does not enter into the combustion erea. It is fed by means of a gallery provided in the bushing area in the secondary cylinder head by means of an elongated hole so that the time that it can be fed with oil under pressure is maximised during each stroke. Galleries are provided in the connecting road which circulete oil through the connecting rod to the outer walls of the piston between the upper and lower piston rings and part is circulated back through the connecting rod and exits into the crenkcase by en exit located low in the connecting rod. A third method of circulating oil is to feed oil under pressure into the power shaft, typically being a cranksheft, of the means of conversion of linear motion to rotary motion, into the connecting rod, through the piston to the cylinder walls, and back through the connecting rod to the crankcase.

In the case of e Scotch yoke being the conversion means the oil can be fed into the vertical linear sliding bearing and into the connecting rod by means of suitable galleries and apertures. Circuletion of oit as above provides the necessary lubrication and elso a means of cooling both the piston and connecting rod.

Another approach to the problem of overheating of the piston is to keep the combustion temperatures within acceptable limits by the means of water injection. Any heat lost to the cylinder walls which then require cooling represents energy which Is lost to atmosphere and if that heat can be turned into useful energy it is beneficial. Optionally the pistons can be made of a heat tolerant material such as ceramic to allow heat to build to higher temperatures than would otherwise be the case and to take adventage of the heat by introducing water into the combustion chamber and for that water to be flashed to steam and to extract additional energy by means described elsewhere herein. The problem of overheating of the connecting rod is alleviated by the fact that it returns to the bushing area on every stroke and can be cooled by immersion in oil or a coolant in this location by means of a suitably sealed gallery filled with the appropriate liquid. Another solution is a design wherein an equivalent rod to the connecting rod continues above the primary piston and through the cylinder head as in the case of the secondary cylinder heads. By travelling into a matching machined cylinder fitted with appropriate means of conveying oil and/or coolant into the rod e.g. a tube sliding within a machined aperture in the rod, fluid can be conveyed to the rod and thence to the piston and then circulated to the bottom of the rod in the case of oil where it is dumped into the crankcase.

The problems with the combustion process caused by the intrusion of the piston rod into the combustion chamber are minimised by the introduction of fuel into the air charge prior to its entry into the cylinder in the case of spark ignition type engines. In the case of direct injection multiple injectors or one injector with multiple points of entry into the cylinder will improve fuel distribution. Also, the fuel can be injected into an aperture in the connecting rod by means of a suitable port in the bushing area, through the connecting rod and past one-way valves or needles so that fuel is distributed from various points on the circumference of the connecting rod into the combustion chamber. Multiple sperk plugs will aid the ignition process or a plate of ceramic or other suitable material can be incorporated between or attached to the secondary cylinder head and cylinder block into which means of conducting the ignition electrical charge are provided and the conduction means are suitably insulated. Electrodes are provided in such block at various parts of the circumference of the aperture which corresponds to the cylinder aperture so that multiple points of ignition are provided. Sealing of the connecting rod can be by means of conventional rings similar to those used in the pistons except that the rings are contained in the stationary bushing area rather than on the moving rod.

The above description includes a second chamber which is used as a combustion chamber. That same chamber can be used for other purposes. For example it can be used as a means of supercharging the engine. Provided with suitable valves such as reed or one-way valves it can take in air on each stroke and pump it under pressure into the inlet manifold. As the chamber takes in close to the same amount of air as the primary combustion chamber (less is inducted due to the connecting rod) and induction and compression occurs twice as often as the induction in the primary combustion chamber a supercharging effect will be generated. A supercharging effect would allow easier transition from 4-cycle to 2-cycle in the primary combustion chambers due to forced scavenging for the primary combustion chambers which is possible when individually actuated valves controlled by the engine management system are used in conjunction with control of entry of fuel by the engine management system.

Another use for the second chamber can be secondary expansion of gases. By means of ports, sliding or other types of valves the exhaust gas generated in the primary combustion chamber can be fed into the second chamber to undergo further expansion and thus give a better thermodynamic efficiency. With individual valve actuation and auxiliary valves plus control of entry of fuel by the engine management system it would be possible to use the chamber for a secondary expansion of gases but have it revert to 4-cycle or 2-cycle combustion of fuel when extra power is required, and this change- over from 4-to 2-cycle is made technically easier when the engine is fitted with a turbo or supercharger to facilitate scavenging in the 2-cycle operation.

Another use for the second chamber is further expansion of gases when water is introduced into the primary and/or secondary chambers. Water can be introduced early or late in the combustion stroke into the primary cylinder and/or early into the introduction of the exhaust gas into the secondary chamber and will be converted to steam by the heat of combustion. When multiple cylinders are used the exhaust/steam gases can be introduced into two secondary chambers so that the pressures on the combined areas of the undersides of the two pistons will be greater than the pressure on the primary single piston when the valves and galleries allow pressure to equalise in the primary cylinder and the two secondary cylinders and the pressure in the two secondary chambers will exert nearly twice the pressure on the undersides of the pistons in the two secondary chambers than the pressure on the primary piston thereby allowing a net generation of power.

An example of a possible use of the chambers as secondary expansion chambers is a basic configuration of one primary chamber and one secondary chamber with inlet and exhaust valves. At the bottom of the combustion stroke in the primary combustion chamber the exhaust valve opens and the exhaust gases are fed into an insulated plenum chamber and also through the inlet port of the secondary chamber to the secondary chamber. Pressure equalises in the primary and secondary chambers and the force exerted on the piston in the primary chamber is greater than that in the secondary chamber due to the lesser cross-sectional area of the underside of the piston due to encroachment by the connecting rod, therefore at this part of the cycle there is a net loss of power compared to a conventional 4-cycle operation.

The exhaust valve in the primary cylinder closes at the top of the exhaust stroke and the plenum is left with hot gases under pressure. The primary cylinder then enters its induction stroke and the secondary chamber enters an exhaust stroke and the secondary cylinder is cleared of gases. The primary cylinder enters its compression stroke and the secondary chamber enters another inlet stroke but the gases in the plenum are under pressure so the inlet stroke is also a power stroke. More power is returned to the piston by this process than was lost in the exhaust stroke in the primary cylinder. The primary cylinder enters its power stroke and the secondary cylinder enters another exhaust stroke. In this manner, more power is extracted from the hot gases than in a conventional 4-cycle process and the thermodynamic efficiency of the engine is increased. The process can be enhanced by the injection of water into the primary and/or plenum and/or secondary chamber to convert the water to steam and to gain advantage of the additional power generated by the expansion of the steam.

In the case of multiple cylinders the process described above can be slightly different. An example is two cylinders in line configured so that the primary combustion chamber in number one cylinder is in its combustion stroke when the combustion chamber in the second cylinder is in its induction stroke. When the exhaust valve in primary cylinder number one opens the exhaust gases are directed to the secondary chambers of both cylinders. Similarly, when the exhaust valve in primary cylinder number two opens the exhaust gases are directed to the secondary chamber of both cylinders. The combined cross-sectional areas of the pistons in the secondary cylinders are nearly double that of each of the cross-sectional areas of the primary pistons and although the pressure of the gases is equalised between one primary cylinder and the pistons in the secondary chamber in the exhaust stroke in that primary cylinder and this exerts a back force against the primary cylinder which would tend to decrease power the net effect throughout the primary and secondary cylinders is an additional generation of power. In this configuration the plenum can be eliminated or minimised.

In any case the manifold acts partly as a plenum. This example is given citing 2 cylinders for simplicity but in practice there would be problems o balance if both pistons moved in unison however the principle would be practical with, for example, a 4-cylinder in-line configuration using pairs of cylinders as in the example.

An alternative use of the additional chambers made possible in this configuration is as follows. The secondary

chambers are used in the supercharging mode as described above but water is sprayed into the air charge either before or after introduction into the chamber under high pressure to provide good atomisation. The chamber is fitted with spark plugs or other means of providing an electrical field, spark or plasma such as a plate of ceramic or other suitable material which is disposed at the top end of the chamber and is provided with multiple electrodes of suitable materials such as platinum to aid the break-down of the water mist into hydrogen and oxygen. A high voltage electrical spark or plasma is applied to break down some of the water mist into hydrogen and oxygen by electrolysis. It has been shown by experiments such as those conducted by Professor Harry Watson of Melbourne University that the introduction of hydrogen into the combustion process is beneficial to the process and it is well known that the introduction of a medium such as NOS which provides oxygen can be a means of generating additional power. A charge composed of part air, hydrogen, additional oxygen and water mist will aid in the generation of power when fuel is introduced (if not already introduced in the induction process into the secondary chamber) by the proven beneficial effects of hydrogen, extra oxygen and water which will flash to steam under the effect of the very high combustion temperatures. Spark or plasma can be generated in the primary combustion chamber with a common electrode material such as platinum the source of this spark or plasma being the ignition spark or a separate spark generated for the purpose to further aid the breakdown of the water mist/steam into hydrogen and oxygen. The injection of water and the subjecting of the charge to the effects of electrical discharge can take place in a separate chamber, in the manifold from the separate chamber to the primary combustion chamber or associated plenum, in the primary combustion chamber or in combinations of the above.

Another example of a configuration meking use of secondary expansion chambers is a 4-cylinder opposed configuration. One pair of cylinders is fitted with one piston on each bank and each cylinder is split into two separate chambers and this bank is used for combustion purposes effectively forming four cylinders. The second cylinder has a lesser crankshaft throw diameter therefore it has a lesser stroke and it also has a larger bore than the other cylinder. The second cylinder is fitted with two cylinders per side and is divided into four chambers per side. Having a lesser stroke this cylinder will not be twice as long as the first cylinder even though it has two pistons and the first cylinder has one. The crankshaft is configured so that when the pistons in the first bank of cylinders is moving in one direction the pistons in the second bank of cylinders is moving in the opposite direction. When a piston in the first bank of cylinders starts its exhaust stroke the exhaust valve opens and the exhaust gas moves into an expansion chamber in the adjacent or equivalent chamber in the second bank and an inlet valve in this chamber is optional and may be eliminated. That chamber then commences a power stroke using the pressure of gases from the exhaust gas. The primary chamber and the secondary chamber are connected at this time so pressure will equalise end there will be a back pressure on the piston in the first cylinder. However, the bore in the second cylinder is greater than that in the second cylinder so the force exerted on the piston in the second cylinder will be greater. The calculations for the bore of the cylinder in the second bank will have to be made keeping in mind the difference in crankshaft throw diameters end therefore of the rotational force imparted to the crankshaft so that the net rotational force imparted to the crankshaft by the expansion chamber in the second cylinder will be greater than the rotational force imparted to the crankshaft by the piston in the first cylinder during the secondery expansion stroke in the second cylinder. At the end of the expansion stroke of the piston in the second cylinder e connection is made through slide or other velves of e port from that chamber to two further expansion chambers in that same cylinder. These would be the two chambers on the opposite side of the two pistons to that of the expansion chamber which has just completed its expansion stroke. This chamber is now connected to the two expansion chambers of identical bore so that this expansion chamber now has a back pressure but this is overcome by the combined pressures on the other two expansion chambers which now begin e tertiary expansion stroke. By this meens more energy is extracted from the exhaust gases and they exheust to atmosphere at a lesser temperature and pressure than would otherwise be the case. In the case where water is introduced into the combustion process and flashed to steam any steam converted to super-heated steam will expand at a very rapid rate but as it cools to saturated steam the speed of expansion poses a problem relative to modern piston speeds. The secondary and tertiary expansions at a lower piston speed allow even saturated steam to expand at a sufficient rate to convey useful energy to the pistons and also to start the condensation process so that the water can be extracted and recovered. For balancing purposes the above example can be put into practice using a four cylinder opposed configuration with combustion cylinders of small diameter opposed by expansion cylinders on the opposing side of larger diameter with the reverse configuration on the adjoining bank.

A system of generation of hydrogen and oxygen can be incorporated so that the resultant gases are piped into the air charge prior to induction. This is a system whereby water with a suitable chemical such as sulphuric acid gives the mixture electrolytic properties and it is stored in an acid-proof container into which two electrodes of a suitable material such as platinum are fitted so that they protrude into the watellelectrolyte mixture. A direct current electric charge is fed to the electrodes and hydrogen is produced at the electrodes by electrolysis. The resultant gases are piped into the inlet manifold for mixing with the charge. The amount of current fed into the gas generator can be made proportional to engine load by suitable circuitry upon command from the engine management system so that the amounts of gases released are proportional to demand. The water converted to gas will be replenished by means of conventional means such as a float which allows water to enter when the level drops. The amount of sulphuric acid will remain theoretically static but would need to be periodically checked and replenished. The benefit in generating and introducing hydrogen and oxygen into the charge is not to gain a direct energy benefit as the amount of energy required to split the water into its components is the same as is gained in re- combination. The benefit is the fact that hydrogen is known to support a leener mixture than e charge with no free hydrogen and allows combustion with an emount of water present that would normally inhibit combustion.

The fact thet hydrogen is present can also be used to advantage by distributing the fuel in the combustion chamber in such a way that a stratified charge is formed and the average mixture can be leaner than would otherwise be practical. Any water introduced preferably should be filtered or distilled.

More than two chambers can be incorporated into each cylinder by means of a further bulkhead or bulkheads or cylinder head/s and another piston or pistons incorporated. The additional bulkhead/s can be used for extra combustion chambers, supercharging chambers and secondary expansion chambers. One sample such configuration would be a conventional primary piston and cylinder arrangement for 2- or 4-cycle combustion with a bulkhead interposed in the cylinder on the other side of that piston so that the underside of the piston and the bulkhead forms a chamber then on the other sida of the bulkhead is another piston so that another chamber is formed between that piston and the bulkhead and then a 4th chamber is formed between that piston and a secondary cylinder head.

The two pistons are connected to the connecting rod and the connecting rod is located in sealed bushings in the bulkheads and secondary cylinder head.

In the example the second and third chambers could be used for supercharging the primary combustion chamber and the secondary combustion chamber formed in the fourth chamber as above. In this configuration cooling of the pistons would be enhanced by the entry of air into the second and third chambers. The second and third chambers could also be used as secondary expansion chambers or they could be used as combustion chambers.

Multi-cylinder arrangements can include in-line configuration, radial, or opposed although some configurations pose problems of balance.

Configurations such as four cylinder opposed pose less problems in obtaining balance. In the case of opposed configuratlons one crenksheft throw can service a pair of cylinders. With a basic arrangement of one pair of in-line cylinders which jointly form four combustion chambers the engine will give the same power output using two cylinders, two pistons, two connecting rods and two crankshaft throws as a conventional four cylinder in-line engine of the same displacement which would require four cylinders four pistons, four connecting rods and four crankshaft throws. By incorporating individually actuated inlet and exhaust valves the engine described herein is given infinitely variable valve timing. Cylinder shut-down becomes e matter of software control and one published article describes trials by the Mercedes Benz compeny whereln they cleim a 25% seving in fuel by means of cylinder shut-down. If the engine is given the ebility to convert from 4- to 2-cycle for bursts of power then it will be able to deliver considerably more power than the equivalent conventional engine. Thus the weight end bulk of the engine can be considerably less than a conventional engine.

Considerable flexibility can be exercised in configuring the layout. For example, although it is beneficial to have cylinders and pistons as one bore size there is no need for this to be the case. For example, a primary combustion chamber could be one size of bore and an expansion chamber could be of another bore size. Another example is that with four cylinders opposed, one cylinder on opposing side but the opposite bank could be of one bore size cylinders to those cylinders could be of another bore size. Also, one cylinder could have one size of crankshaft throw and another a different size i.e. the two cylinders would have different strokes. The reason for this can be thet one cylinder is used for combustion purposes and the other for secondary expansion purposes e.g. when steam is added to the combustion gases and it is desired to allow a slower expansion rate when the steam turns from super-heeted steam to saturated steam and the expansion is slower. In such alternate configurations the requirement to balance the engine will have to be taken into account and this can be, for example, by adding pairs of like opposed cylinders or pairs of like in-line cylinders. Other means of balancing such as counter-weights or counter-shafts can be used.

When water is added to the air charge as described above provision can be made to recover the bulk of the weter through secondary expansion allowing condensetion and recovery of the water by using techniques well known in the design of steam engines.

Water can be included in fuel by mixing it with a suitable emulsifier and surfactant. A number of such emulsifiers have been identified and tested end results published over many years. The engine herein can have water introduced into the combustion process by a fuel/water/emulsifier mix. An emulsifier which has electrolytic properties or has an additional chemical added which is not detrimental to the combustion process or to the mechanical components of the engine but has electrolytic properties or has the ability to enhance the breakdown of water into hydrogen and oxygen during electrolysis would be of benefit to the operation of the engine when provision is made to provide a means of electrolysis in the various passages that the air charge or exhaust gases travel through during the operation of the engine.

The various chambers in the engine can be used for multiple purposes by means of suitable control of the inlet and exhaust valves and fuel injection system by the engine management as well as auxiliary valves in certain cases by the engine management system. For example one chamber can be used as a secondary expansion chamber and if additional power is reouired the operetion of the cvlinder can be switched so that it ooerates as a combustion

chamber.

The cylinders can be made in one piece or in sections and joined to other sections of the cylinders using dowels and pins to effect alignment.

When the supercharging facility as described herein is used or when an external turbocharger or supercharger is used the cycle known as the Miller cycle can be introduced at any time when there is sufficient boost in the inlet manifold to support the Miller cycle by means of commands from the engine management system to the valve actuators.

An embodiment of the invention provides a design which can make efficient use of inlet and exhaust valves which are actuated by electro- mechanical, electrohydraulic, electromagnetic or other similar actuators and which are controlled by electronic means by an engine management system.

Although the basic design can be operated by conventional poppet valves the use of individually actuated valves simplifies the mechanical layout, which is complex if multiple camshafts are required. The use of individually actuated and controlled inlet and exheust valves also allows a number of other advantages including the ability to eliminate or minimise the use of throttle end ellow control of the air/fuel charge by means of early or late closure of the inlet valves, to ellow change-over from 4-cycle to 2-cycle and other benefits.

A further embodiment of the invention provides a design in which provision can be made to shut down cylinders under conditions of light load to effectively give variable displacement. The advantage of cylinder shut- down is that those cylinders which continue to operate can operate at a higher compression than would be the case if all cylinders were operating and therefore efficiency is higher. Cylinder shut-down can be readily achieved by the engine management system when individual valve actuation and control is utilised.

A still further embodiment of the invention provides a system in which water can be introduced into the air charge and converted to steam by means of the heat of combustion end the expansion of the steam used to add power to the engine. The fact thet the provision of expansion chambers is made relatively eesy with this design means that expansion chambers can be utilised to give secondary expansion to exhaust gas/steam combinations.

Yet a further embodiment of the invention provides a system in which water can be broken down into hydrogen end oxygen by means of electrolysis and introduced into the air charge with the intention of providing a better combustion process in the presence of weter end/or better combustion with a leaner mixture or a stratified charge.

Brief Description of Drawings In the schematic representations of the embodiments depicted in the drawings, the means of converting linear motion to rotary motion, where depicted, is a Scotch yoke.

Fig. 1 is a schematic representation of a single cylinder engine with one cylinder and 2 combustion chambers; Fig. 2 is a schemetic representation of 2 methods of lubricating and/or cooling the piston and connecting rod in Fig. 1; Fig. 3 is a schematic representation of a twin opposed variant of the engine in Fig. 1; Fig. 4 is a schematic representation of a varient of the engine in which the secondary chamber is used to supercharge the primary cylinder depicted in the compression stroke; Fig. 5 is as in Fig. 4 in the combustion stroke; Fig. 6 is as in Fig. 4 in the exhaust stroke; Fig. 7 is es in Fig 4 in the intake stroke; Fig. 8 is a schematic representation of two cylinders with the primary chambers being used as combustion chambers and the secondary cylinders being used as supercharging chambers with the left primary combustion chamber in its exhaust stroke and the right hand combustion chamber in its compression stroke.

Fig. 9 is as in Fig. 8 but with the left hand combustion chamber in its intake stroke and the right hand combustion chamber in its combustion stroke; Fig 10 is as in Fig. 8 but with the left hand combustion chamber in its compression stroke and the right hand combustion chamber in its exhaust stroke.

Fig. 11 is as in Fig. 8 but with the left hand combustion chamber in its combustion stroke and the right hand combustion chamber in its intake stroke; Fig. 12 is a schematic representation of an embodiment of an engine in which two pistons are attached to each connecting rod and a dual cylinder head is disposed between each cylinder head with two chambers used es combustion chambers and two chambers used as supercharging chambers; and Fig. 13 is a schematic representation of the engine in Fig. 12 in its next cycle.

Best Modes for Carrying Out the Invention Referring to Fig 1 double sided piston 1 slides in a linear and sinusoidal motion within cylinder 2 and is rigidly connected to connecting rod 3 which slides through bushings (not shown) in secondary cylinder head 14 end connects to Scotch yoke mechanism 5 where it can convey power by means of eccentric 6 to crankshaft 7. A primary cylinder head 13 is fitted in which is installed inlet valve 9 and exhaust valve 10 which are actuated by actuating mechanisms not shown. Secondary cylinder head 14 is fitted with inlet valve 11 and exhaust valve 12 which ere actuated by actuating mechanisms not shown. This embodiment has a primary combustion chamber 13 and a secondarv combustion chamber 15 as well as crankcase 8.

In operation, piston 1 moves towards cylinder head 13 in its exhaust stroke end gas is exhausted through open exhaust velve 10 through exhaust port 22 and at the same time valves 11 and 12 ere closed and combustion is occurring in combustion chembers 15 and 19 and exerting force on piston 1 at face 16 while velves 11 and 12 are closed. Piston 1 then reverses direction due to the action of the crenkshaft end Scotch yoke mechanism end inlet valve 9 opens and air/fuel (or air in the case of a diesel engine or direct injection) is inducted through inlet port 21 into chamber 18 and at the seme time exhaust valve 12 opens and exhaust gases exit through exhaust port 24 from chamber 19.

The piston 1 then commences a return stroke, valves 9 and 10 are closed and air/fuel (or air) in chamber 18 is compressed and at the same time inlet valve 11 opens and eir/fuel or air is inducted into chamber 19 through inlet port 23. The piston 1 then reverses direction again, fuel is injected into chamber 13 in the case of a diesel engine or direct injection by means not shown and ignition is initiated by means not shown or by compression ignition in the case of a diesel engine and a combustion stroke commences and pressure is exerted on piston 1 at face 17. At the same time valves 11 end 12 are closed and air/fuel or eir is compressed in chember 19. As piston 1 approaches secondary cylinder head 14 fuel is injected in the case of a diesel engine or direct injection and ignition is initiated by means not shown or by compression ignition in he case of a diesel engine and chamber 15 commences a combustion cycle when the piston reverses. The cycle is then ready to be repeated. In this example chamber 18 is in an exhaust cycle when chamber 19 is in e combustion cycle. When chamber 18 is in an exhaust cycle chember 19 can be in en intake cycle and the other cycles for chamber 19 are all shifted in sequence i.e intake is followed by compression, combustion and then exhaust.

Referring to Fig. 2, two alternative methods of providing lubrication and/or cooling to the piston and connecting rod are shown. In the first method oil is fed under pressure through cylinder wall 2 by gallery 25 to the inner part of the wall between the rings on piston 1. It circulates back through aperture 26 in piston 1 through gallery 26 to aperture 27 in connecting rod and exits to the crenkcase erea.

In the second method oil is fed under pressure to elongeted port 29 and when aperture 35 is adjacent to port 29 oil is forced into eperture 35 through e one-way valve located at position 31 and then through gallery 33 to the piston walls end is re-circulated through gallery 34 to port 35 where it exits to the crankcase area.

Fig. 3 shows a twin opposed configuretion of the engine depicted in Fig. 1. The reference numerals correspond to equivelent elements of those in Fig. 1.

Fig. 4 depicts a variant of the engine in which the secondary chamber is used es e means of supercharging the primary piston. It is depicted on the compression stroke. Piston 1 is moving towards cylinder head 4 and both valves 9 and 10 are closed es eir/fuel is compressed in chamber 18. Air is drawn in through inlet manifold 39 past throttle 40 to inlet port past one-way valve (typically a reed valve) 37 into chamber 38 end one-way valve 36 is closed.

Fig. 5 is the same as Fig. 4 with the primary cylinder on its combustion stroke. The piston 1 is now moving away from cylinder head 4 and valves 9 and 10 are closed. The air in chamber 38 is forced pest one-way valve 37 Into manifold/plenum 41.

Fig. 6 is the same as Fig. 4 with the primary cylinder on its exhaust stroke. Piston 1 agein moves towards cylinder head 4 and the exhaust valve opens. Air is drawn into chamber 38 past one-way valve 37 and one-way valve 36 has shut, trapping air under pressure in manifold/plenum 41.

Fig. 7 is the same as Fig. 4 with the primary cylinder on its intake stroke. Piston 1 moves away from cylinder head 4 end eir is forced from chamber 38 into manifold/plenum 41 and pest open one-way valve 36 into open inteke valve 9 into the primary combustion chamber 18. As the secondary cylinder pumps twice in each 4 cycle operation a pressure builds up to supercharge chamber 18.

Fig. 8 depicts two cylinders in an engine as in Fig. 4 showing the sequence and flow of this type of engine when multiple cylinders are involved. Combustion chamber 18 is in its exhaust stroke and piston 1 is moving towards exhaust valve 10 which is open. One-way velve 36 is open and admits eir/fuel into chamber 49. Combustion chamber 47 is in its compression stroke and piston 48 is moving towards valve 45 with both valves 44 and 45 closed and air is inducted into chamber 50 through one-way valve 37. One-way valves 51 and 52 are closed.

Fig. 9 is as in Fig. 8 but in the next cycle. The pistons in both chambers are moving towards the one-way valves 36 and 37. Chamber 18 is in its intake stroke and air that has been compressed in chambers 49 end 50 passes through one-way valves 52 and 51 through manifold 46 through open inlet valve 9 into chamber 18. Chamber 47 is on its combustion stroke and both valves 44 and 45 are closed.

Fig. 10 is as in Fig. 9 but in the next cycle. The pistons in both chambers 18 and 47 are moving towards valves 10 and 45. Chamber 18 is in its compression stroke with both valves 9 and 10 closed. Air is inducted into chambers 49 and 50 in the same way as in Fig. 8. Chamber 47 is in its exhaust stroke and exhaust valve 44 is open.

Fig. 11 is as in Fig. 10 but in the next cycle. The pistons in both chambers 18 and 47 are moving towards one-way valves 36 and 37. Chamber 18 is in its combustion stroke with both valves 9 and 10 closed. Chamber 47 is in its intake stroke and inlet valve 45 is open. Air is compressed in chambers 49 and 50 in the same way as in Fig. 9 and air is forced through one-way valves 51 and 52 through manifold 46 into chamber 47.

Fig. 12 depicts an embodiment of an engine with two pistons attached to the one connecting rod with a bulkhead or dual cylinder head between the two pistons. In this particular configuration the additional chambers so formed are depicted as supercharging chambers. Pistons 1 and 48 move towards valve 9 and chamber 18 is in its compression stroke. Chamber 53 is in its induction stroke and intake valve 11 is admitting air/fuel under pressure from manifold 46. Chamber 50 is compressing ahlfuel which is being forced past one-way valve 36 into manifold 46. Aillfuel is being inducted into chamber 49 through inlet manifold 39 through one-way valve 51.

Fig. 13 is the same as Fig. 12 but in the next cycle. The pistons 1 and 48 move towards valve 11 and chamber 18 is in its combustion stroke with valves 9 and 10 closed. Chamber 53 is in its compression stroke with valves 11 and 12 closed. Air is being inducted into chamber 50 through inlet manifold 39 past open one-way valve 52. Air is being compressed in chamber 49 and forced past one-way valve 37 into manifold 46 where pressure builds up. The next two cycles are not depicted but it can be seen that in four cycles four compression strokes occur from chambers 49 and 50 compared to two induction strokes that occur in chambers 18 and 53 so pressure builds in manifold 46 and chambers 18 and 53 are supercharged.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

(WO/1998/049434) INTERNAL COMBUSTION ENGINE

CLAIMS: 1. An internal combustion engine including a piston rigidly coupled to a connecting rod, said piston being fitted within a cylinder having a chamber at each end thereof, said connecting rod passing out of the cylinder through an end face of at least one of said chambers, at least one of said chambers being a combustion chamber and said connecting rod being coupled to means for converting linear motion to rotary motion.

2. An internel combustion engine as claimed in claim 1 wherein each combustion chamber includes inlet and exhaust velving means controlled by electronic means.

3. An internal combustion engine as claimed in claim 1 wherein each chamber includes inlet and exhaust valving means controlled by electronic means.

4. An internal combustion engine as c'almed in claim 1 or 2 wherein the electronic means is an engine management system.

5. An internal combustion engine as claimed in claim 1 or 2 wherein at least one peir of cylinders are arrayed in en opposed configuration.

6. An internal combustion engine as claimed in claim 1 or 2 wherein at least two cylinders are arrayed in an in-line configuration.

7. An internal combustion engine as claimed in claim 1 or 2 wherein at least two cylinders are arrayed in a vee configuration.

8. An internal combustion engine as claimed in claim 1 or 2 in which multiple cylinders are arrayed in e radial configuration.

9. An internal combustion engine as claimed in any one of claims 1 to 8 wherein the piston/s and/or connecting rod/s are lubricated and/or cooled by a lubricant which is circulated under pressure through the walls of the cylinder/s to the piston/s and to the connecting rod end re-circulated to a reservoir.

10. An internal combustion engine as claimed in any one of claims 1 to 8 wherein the pistols and/or connecting rod/s are lubricated/and or cooled by a lubricant which is circulated under pressure through an elongated aperture to a port in the connecting rod through such rod to the pistons and piston walls and re-circulated through the rod back to a reservoir.

11. An internel combustion engine as claimed in any one of cleims 1 to 8 wherein the piston/s and/or connecting rods are lubricated and/or cooled by a lubricant which is circulated under pressure through a shaft which conducts power generated by the engine to the meens of converting linear motion to rotary motion end thence to the connecting rod/s through the connecting rod to the piston walls and is re-circulated back through the connecting rod/s to reservoir.

12. An internal combustion engine as claimed in claim 10 wherein the flow of oil to the aperture in the cylinder wall can be interrupted when predetermined ereas of the piston do not cover such aperture.

13. An internal combustion engine as claimed in any one of claims 1 to 12 wherein at least one of the chambers formed by the movement of the piston in a cylinder is adapted to induct and compress an air charge or a combustible

charge and to exhaust such charge under pressure into an outlet manifold and to an inlet port of a combustion chamber.

14. An internal combustion engine as claimed in claims 1 to 12 wherein at least one of the chambers is adapted for further expansion of gases exhausted from the combustion chamber.

15. An internal combustion engina as claimed in any one of the preceding claims wherein at least a cylinder head of each combustion chamber is fitted with a layer of a non-conductive heat-resistant material such as a ceramic material with an aperture corresponding to the cylinder aperture such layer being a separate layer to or bonded to the cylinder haad and such layer incorporating at least one means of conducting electricity to the walls of the aperture corresponding to the cylinder aperture and fitted with electrodes for discharging an electrical spark or generating a plasma with in the chamber to like electrodes fed by different electrical means or to the surrounding conducting materials.

16. An internal combustion engine as claimed in claim 15 wherein at least one chamber is a compression or expansion chamber fitted with a layer of non-conductive heat-resistant material on the interior surface of the head of that chamber, such layer incorporating means for conducting electricity to the head of the cylinder to a location at which electrode means are adapted to generate an electrical spark or plasma.

17. An engina as claimed in any one of claims 1 to 11 wherein a bulkhead forming a cylinder head is comprised of a cylindrical portion closely machined so that it fits closely into the cylinder and is fitted with rings or seals at its outer circumfarence and a sealed bushing at its cantre to accommodate the connecting rod and which cylindar head cylindrical portion is adapted to be locked into place in the cylinder.

18. An engine as claimed in any one of claims 1 to 17 comprising at least two cylinders fitted and whereln at least one cylindar is of a different bore to at least one other cylinder.

19. An engine as claimed in any one of claims 1 to 18 wherein at least one cylinder is formed with differing bores.

20. An engine as claimed in any one of claims 1 -19 when being powered by a mixture of fuel, water and emulsifier.

21. An engine as claimed ln claim 20 wherein the fuel contains an additive which is an electrolyte or has chemical properties which aid the breakdown of water into hydrogen and oxygen during electrolysis.

22. An engine as claimed in any one of claims 1 to 21 wherein at least one chamber is adapted to be used as a combustion chamber or as an expansion chamber or as a compression chamber.

23. An engine as claimed in claim 2 wherein the valving means are selected from poppet, slide, rotatable and reed valves.

24. An engine as claimed in any one of claims 1 to 23 wherein the engine is adapted to be switched from 4-to 2-cycle or 2- to 4-cycle operation by the alteration of commands from-an engine management system.

25. An engine as claimed in any one of the praceding claims adapted to operate as a Miller cycle engine undar tha control of an engine management system.

26. An engine as claimed in any one of the preceding claims which comprises at least two combustion chambers and wherein at least one combustion chamber is adapted to be shut down by means of alteration of commands from an engine management system to the valving means and to means supplying fuel to the combustion chambers.

27. An engine as claimed in any one of the preceding claims comprising a connecting rod disposed on both sides of all pistons.

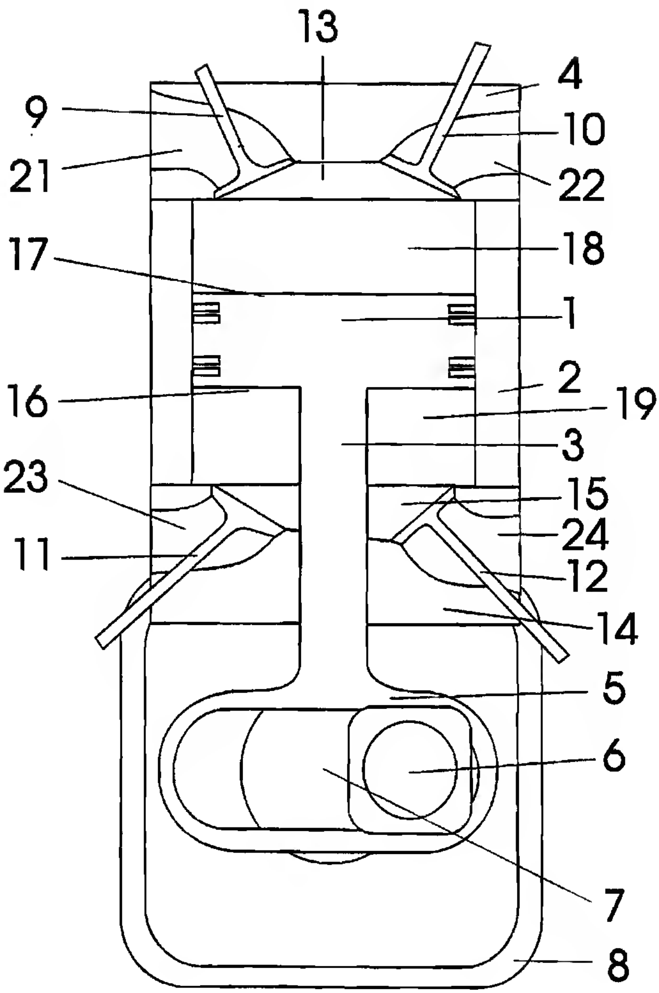

FIG 1

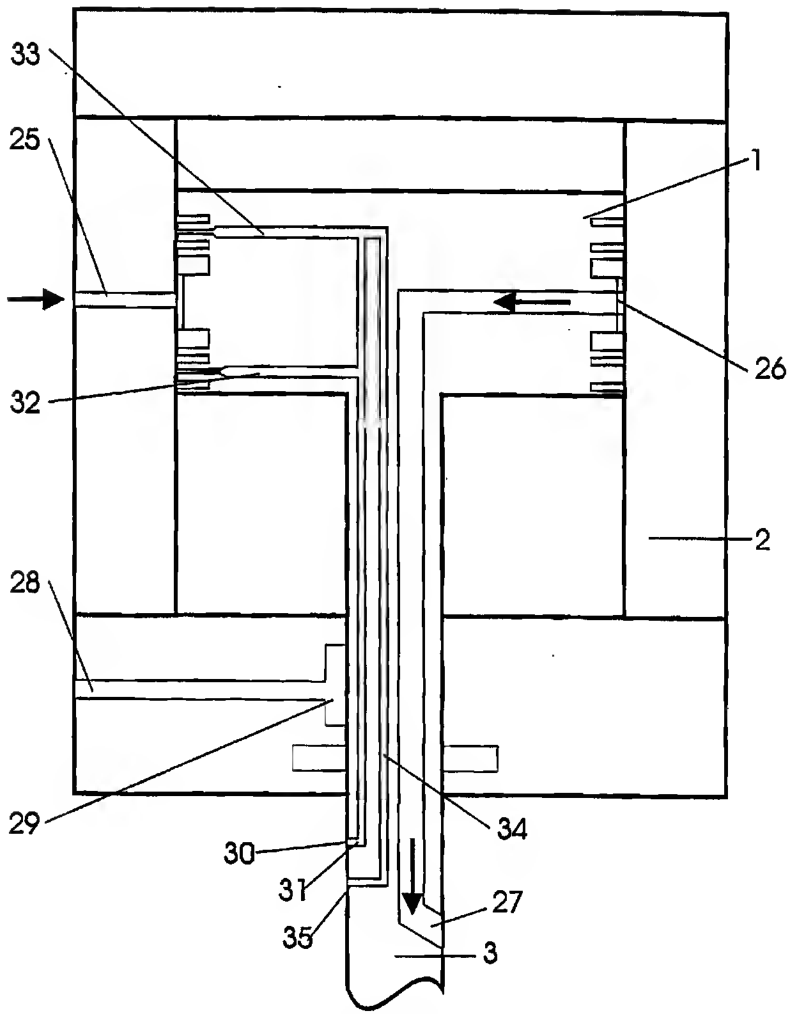

FIG 2

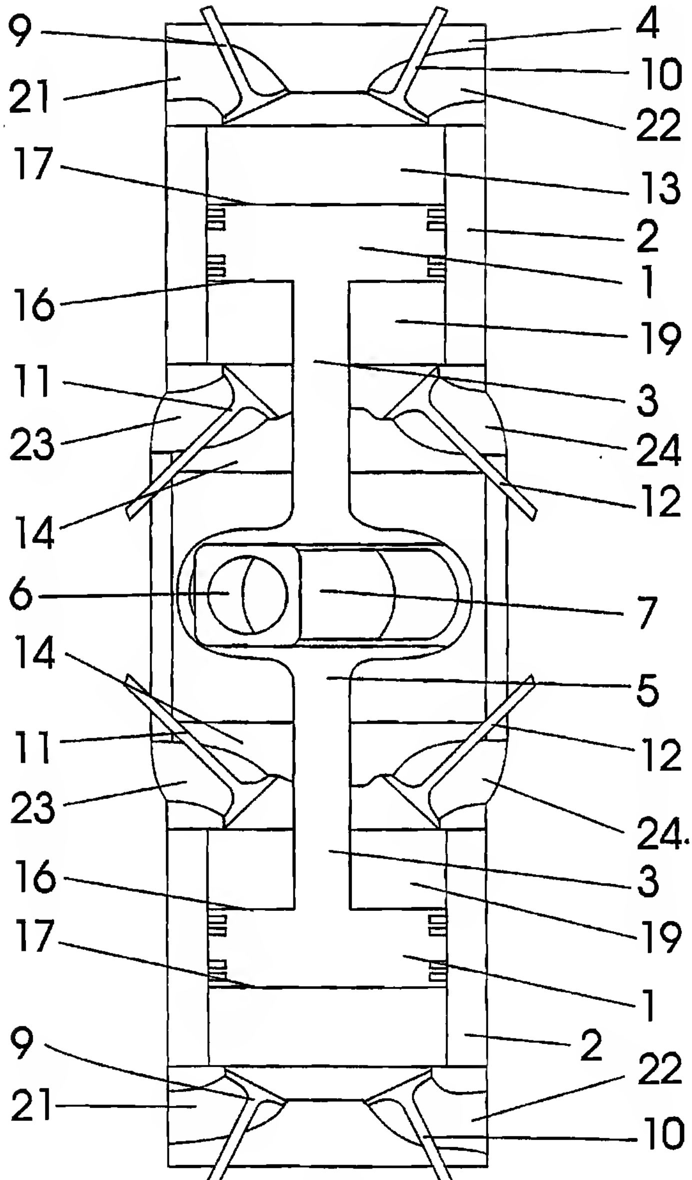
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FIG 3

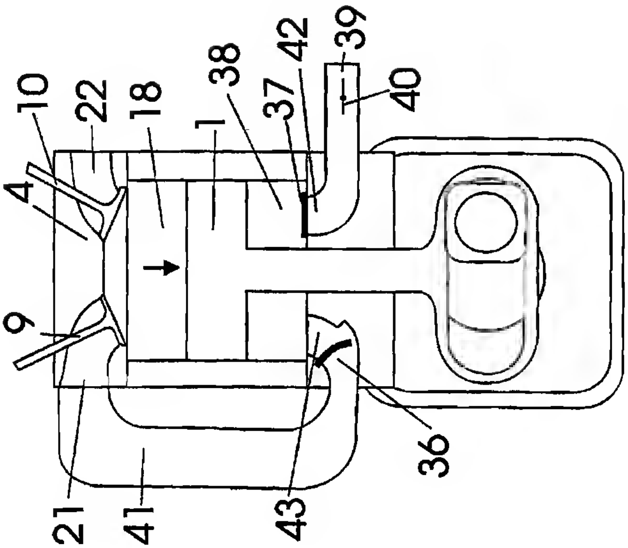
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FIG 5

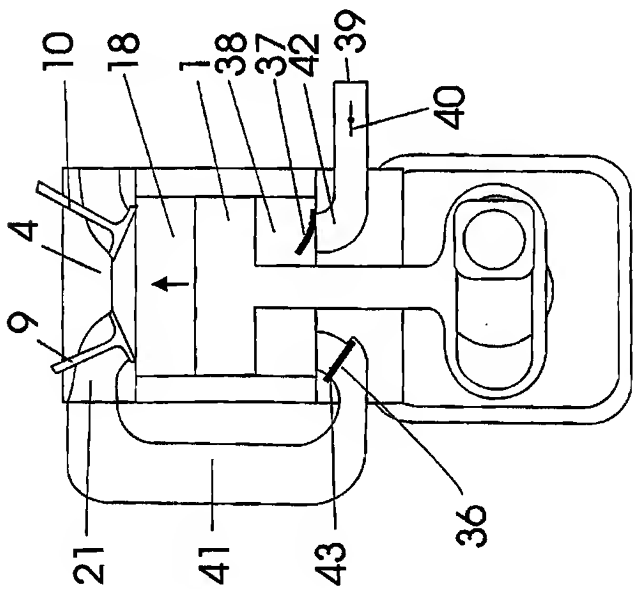
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FIG 4

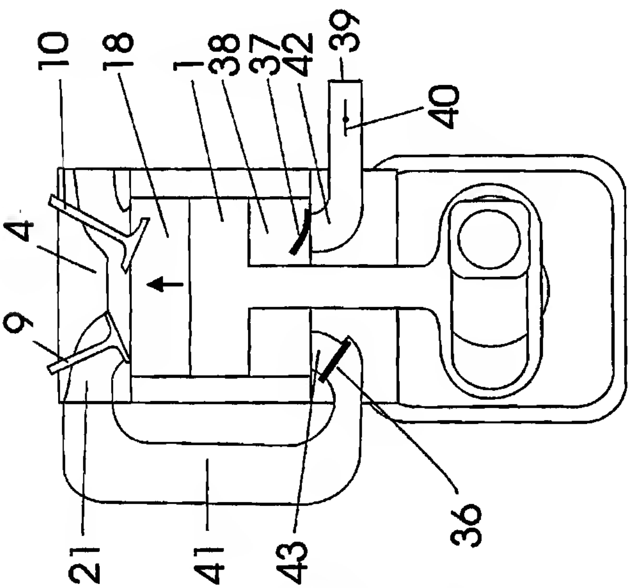

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FIG 6

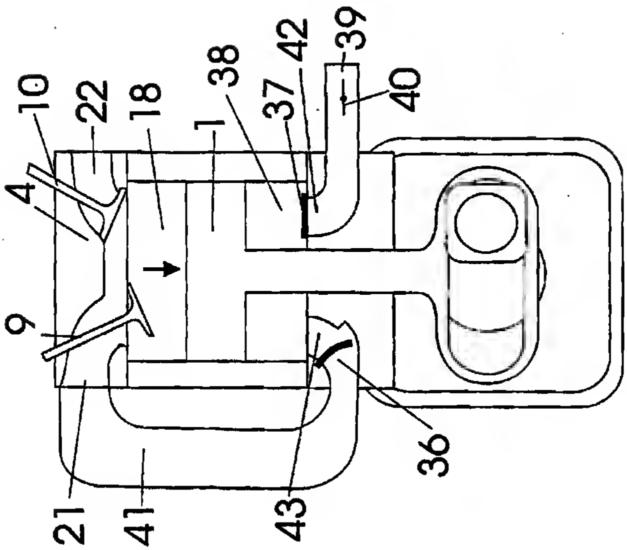

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FIG 7

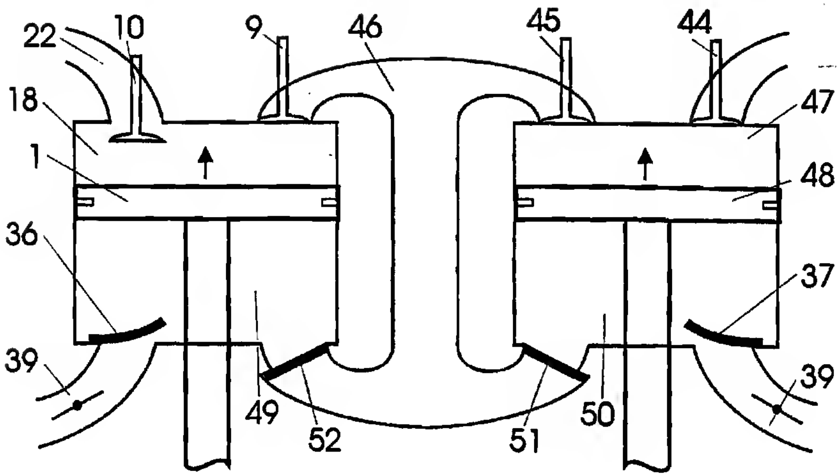
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FIG 8

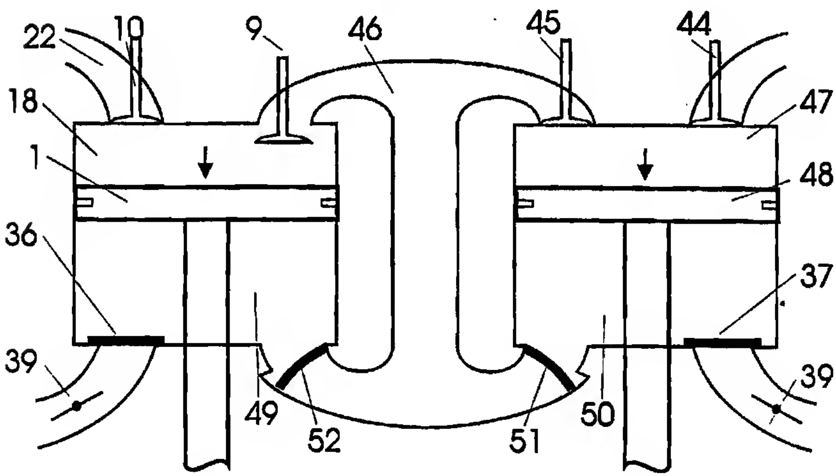
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FIG 9

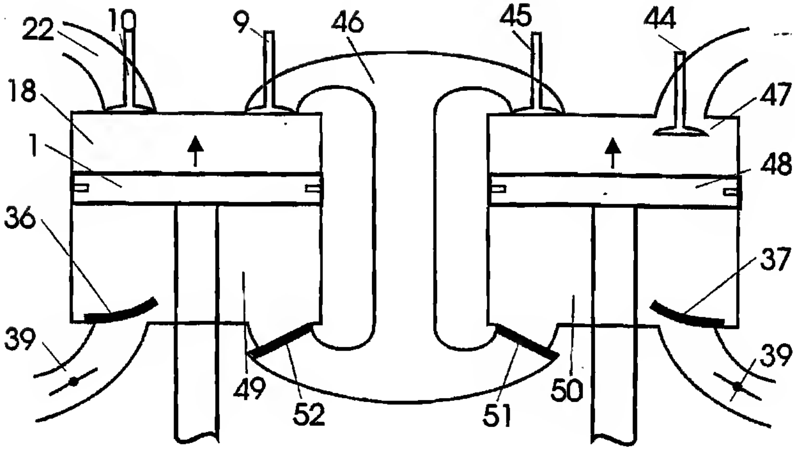
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FIG 10

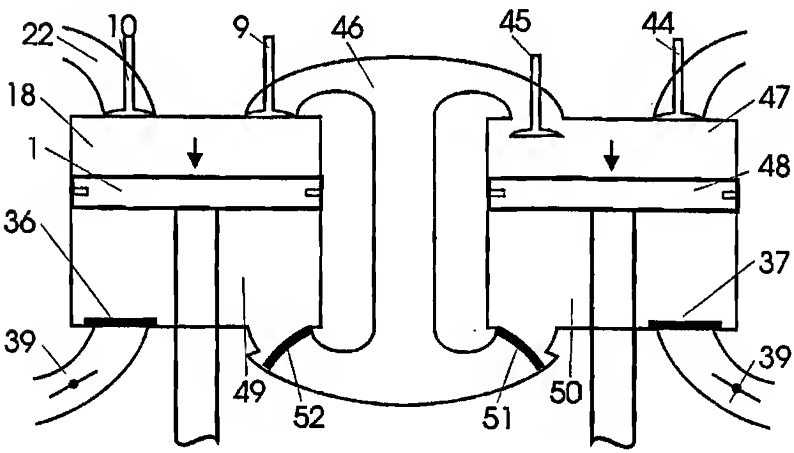
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FIG 11

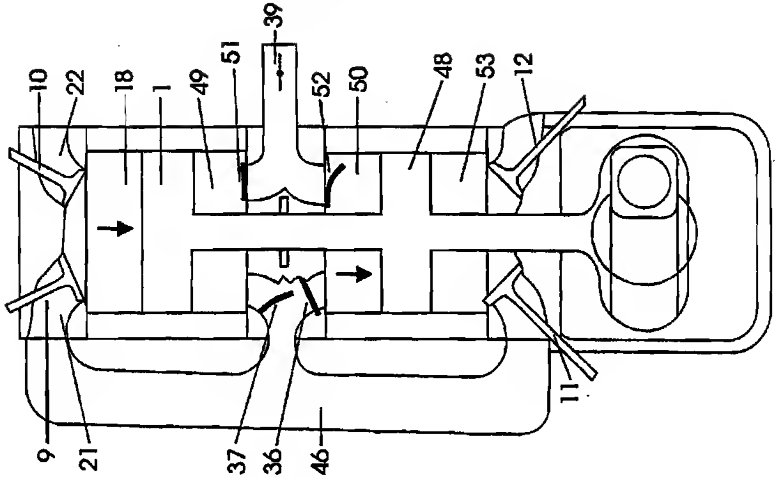
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FIG 13

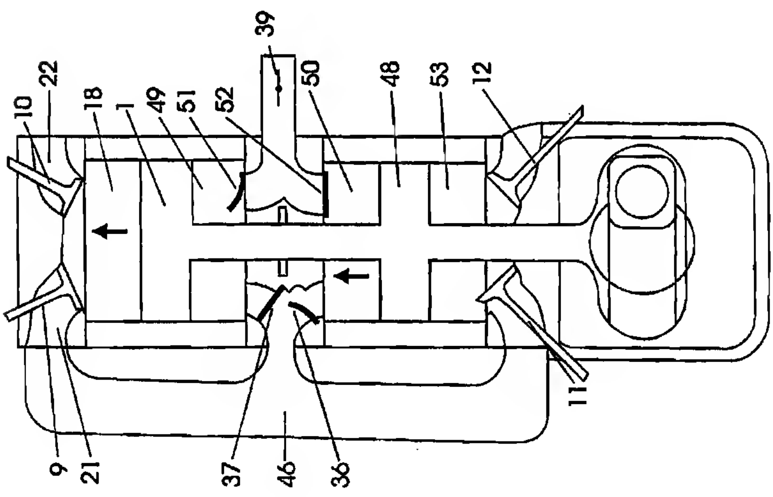
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FIG 12

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 98/00300

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: F02B 33/10, 75/24, 75/28, 75/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : F01B, L, M, P, F02B, F02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : classification marks as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT & JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9602744 A1 (SKRIPOV) 2 January 1996 see all figures	1-2,4-8,13,17,20-23
X	Derwent Abstract Accession no 94-277929, RU 2008474 C1 (ZELENIN) 28 February 1994 abstract	1-8,17-26
X	DE 4011140 A (BOHNE) 17 January 1991 figures 1-2	1,5-8,13,17-22
X	EP 238996 A2 (HALL) 30 September 1987 figure 3	1,4-8,13,17,20-22

☐ Further documents are listed in the continuation of Box C

☒ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 June 1998	26 JUN 1998
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (02) 6285 3929	Authorized officer JAGDISH BOKIL Telephone No.: (02) 6283 2371

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 98/00300

Box 1 Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claim No.: 27
   because it relates to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
   The invention of claim 27 is not fairly disclosed in the specification.

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see extra sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1-8, 13-14, 17-26

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 98/00300

Box II continued

The international application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. In coming to this conclusion the International Searching Authority, has found that the claims as a whole define five different inventions according to the claim/claim groups identified below. These claims/claim groups are each characterised by their own distinctive technical features which can *prime facie* be considered to comprise "special technical features" (as per PCT Rule 13.2. last line) as follows:

Claim 3:
each chamber including exhaust and inlet valving means controlled by electronic means

Claims 9-12:
means for lubrication/cooling as defined including flow of lubricant/coolant through the piston, connecting rod and/or a power shaft

Claim 14:
at least one chamber forming an expansion chamber for expansion of gases exhausted from the combustion chamber

Claims 15-16:
the cylinder head having a non-conductive heat-resistant layer incorporating electrodes

Claim 19:
at least one cylinder being formed with differing bores

Whilst claim 1 defines a combination of features which is clearly common to all the claims, such a combination of features cannot be considered to comprise a "special technical feature" according to Rule 13.2, since the combination is clearly well known in the light of many patent disclosures in the international patent classification mark F02B 33/10 (see eg. EP 238996A))and therefore cannot be considered to make a contribution over prior art.

Since the abovementioned groups of claims do not share any of the special technical features identified, a "technical relationship" between the inventions, as defined in PCT rule 13.2 does not exist. Accordingly the international application does not relate to one invention or to a single inventive concept, *a posteriori*.

Claims 1-2, 4-8, 13, 17-18, 20-26 each fail to define any "special technical feature" at all. Each of these claims defines a combination of features which is either

- clearly well known (eg claim 1 as stated above), or
- is clearly a non-inventive combination of otherwise separately known features(eg. claim 24 additionally defines the feature of a dual cycle arrangement which is known in the art and which does not bear a working relationship with features of previous claims to produce a surprising or an improved result. The combination of claim 24 cannot therefore be considered inventive)

These claims are therefore considered not to include any feature which would make a contribution over the prior art.

Consequently, these claims fail to define any "special technical feature" according to Rule 13.2.

Despite the existence of several claimed inventions in this application, it was considered that the different inventions of claims 3, 14, 19 (effectively claims 1-8, 13-14, 17-26) could be covered by the single search fee paid.

The two separate additional inventions defined by the claim groups (a) 9-12 and (b) 15-16, have not been searched as two requested additional search fees were not paid by the due date.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No.
PCT/AU 98/00300

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	9602744	AU	29392/95	EP	785347		
EP	238996	AU	7064487	CN	87102814	DK	1437/87
		HU	48325	JP	62240433	NO	871130
		US	4791892	ZA	8702033		

END OF ANNEX